

AD-A098 627

DECISIONS AND DESIGNS INC MCLEAN VA

F/G 15/4

INTELLIGENCE PREPARATION OF THE BATTLEFIELD: CRITIQUE AND RECOM--ETC(U)

FEB 81 L ADELMAN, M L DONNELL, R H PHELPS

MDA903-79-C-0275

UNCLASSIFIED

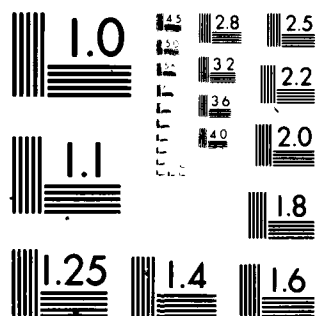
PR-81-5-304

NL

[P]  
AD-A098 627



END  
DATE  
FILMED  
6-8h  
DTIC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

AD A098627

III

6

12

February 1981

FINAL REPORT PR 81-5-304 ✓

# Intelligence Preparation of the Battlefield: Critique and Recommendations

ABRIDGED VERSION

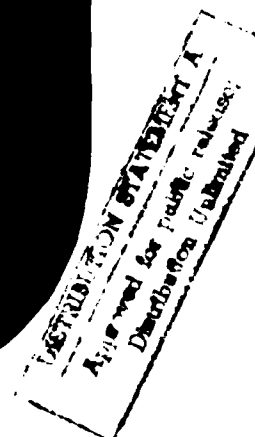
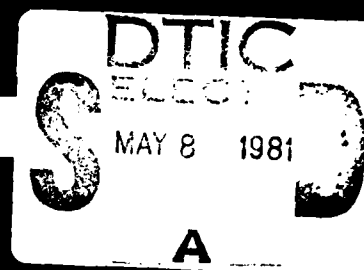
A096691

Leonard Adelman  
Michael L. Donnell  
Decisions and Designs, Inc.

Ruth H. Phelps  
U.S. Army Research Institute

THE VIEWS, OPINIONS, AND FINDINGS CONTAINED IN THIS REPORT ARE  
THOSE OF THE AUTHORS AND SHOULD NOT BE CONSTRUED AS AN OFFICIAL  
DEPARTMENT OF THE ARMY POSITION, POLICY, OR DECISION, UNLESS SO  
DESIGNATED BY OTHER OFFICIAL DOCUMENTATION.

DECISIONS and DESIGNS, INC.



23 053

Prepared for  
U.S. Army Research Institute  
Contract MDA903-78-C-0276

**FINAL REPORT PR 81-5-304**

**INTELLIGENCE PREPARATION OF THE BATTLEFIELD:  
CRITIQUE AND RECOMMENDATIONS  
ABRIDGED VERSION**

by

*Leonard Adelman and Michael L. Donnell*  
Decisions and Designs, Inc.

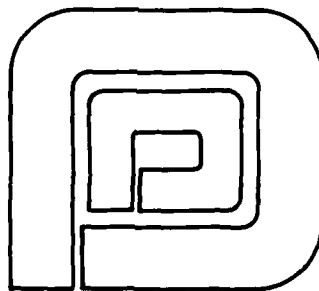
and

*Ruth H. Phelps*  
U.S. Army Research Institute

Prepared for

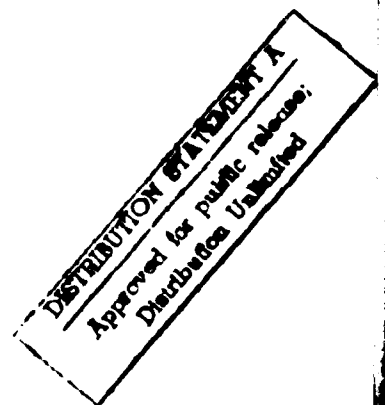
U.S. Army Research Institute  
5001 Eisenhower Avenue  
Alexandria, Virginia 22333  
Contract MDA903-79-C-0275

February 1981



**DECISIONS and DESIGNS, INC.**

Suite 600, 8400 Westpark Drive  
P.O. Box 907  
McLean, Virginia 22101  
(703) 821-2828



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE  |                                     | READ INSTRUCTIONS<br>BEFORE COMPLETING FORM                    |
|--|-------------------------------------|--|
| 1. REPORT NUMBER<br>PR-81-5-304  | 2. GOVT ACCESSION NO.<br>AD-A098627 | 3. RECIPIENT'S CATALOG NUMBER                                  |
| 4. TITLE (and Subtitle)<br>INTELLIGENCE PREPARATION OF THE BATTLEFIELD:<br>CRITIQUE AND RECOMMENDATIONS (Abridged Version)   |                                     | 5. TYPE OF REPORT & PERIOD COVERED<br>Final Report             |
| 7. AUTHOR(s)<br>Leonard/Adelman<br>Michael L./Donnell<br>Ruth H./Phelps  |                                     | 6. PERFORMING ORG. REPORT NUMBER                               |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Decisions and Designs, Inc.<br>Suite 600, 8400 Westpark Drive, P. O. Box 907<br>McLean, VA 22101  |                                     | 8. CONTRACT OR GRANT NUMBER(s)<br>MDA903-79-C-0275             |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>U. S. Army Research Institute<br>5001 Eisenhower Avenue<br>Alexandria, VA 22333   |                                     | 10. PROGRAM ELEMENT, PROJECT, TASK<br>AREA & WORK UNIT NUMBERS |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)  |                                     | 12. REPORT DATE<br>February 1981                               |
|  |                                     | 13. NUMBER OF PAGES<br>58                                      |
|  |                                     | 15. SECURITY CLASS. (of this report)<br><br>UNCLASSIFIED       |
|  |                                     | 15a. DECLASSIFICATION/DOWNGRADING<br>SCHEDULE                  |
| 16. DISTRIBUTION STATEMENT (of this Report)<br><br>Approved for public release; distribution unlimited   |                                     |  |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)   |                                     |  |
| 18. SUPPLEMENTARY NOTES<br><br>For an unabridged version of this report, see PR 81-4-304   |                                     |  |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>Tactical intelligence      Decision analysis      Circular TC30-27<br>Combat intelligence      Decision aids      Circular TC34-3<br>Threat evaluation      Computer-aided analysis<br>Decision theory      Judgment (psychology)<br>Battlefields  |                                     |  |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>Intelligence preparation of the Battlefield (IPB), outlined in Circulars TC30-27 and TC34-3, represents a major step toward improving procedures for correlating data with enemy intent. The purpose of this report is to show how IPB could be improved by incorporating decision-analytic techniques and computerized decision aids to improve the judgmental process inherent within IPB.<br><br>The first section of this report describes the necessary dependence |                                     |  |

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

790644

**UNCLASSIFIED**

**SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)**

on human judgment. This section identifies the different types of judgment inherent in each of the five steps in the IPB analysis process proposed in TC30-27 and TC34-3. The general conclusion is that except for terrain analysis and weather analysis, these circulars fail to tell intelligence analysts how they are to make the judgments necessary to implement the proposed IPB analysis process.

The second section of this report describes the results of research studying how well people make the judgments inherent in IPB. The research strongly suggests that people's ability to make these judgments can be improved substantially by training them in decision-analytic techniques and by giving them access to computerized judgment aids. Two judgment aids incorporating decision-analytic techniques are described in detail, for they are designed to assist Staff Intelligence Officers (G2/S2s) in looking at the battlefield from the perspective of the enemy commander. Since both aids provide displays designed to help analysts convey the reasons for their judgments to tactical commanders, they provide an adjunct to the graphic templating process proposed in IPB. Scientific research will improve (1) the cognitive skills and, thus, judgmental accuracy of intelligence analysts developing IPB templates, and (2) the communication process for conveying the reasons for these judgments to tactical commanders.

|                    |  |
|--------------------|--|
| Accession For      |  |
| FTS GNA&I          | <input checked="checked" type="checkbox"/> |
| FTS TAB            | <input type="checkbox"/>                   |
| Unannounced        | <input type="checkbox"/>                   |
| Justification      |  |
| Distribution/      |  |
| Availability Codes |  |
| Avail and/or       |  |
| Special            |  |
| A                  |  |

**UNCLASSIFIED**

**SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)**

## CONTENTS

|  | <u>Page</u> |
|--|-------------|
| <b>FIGURES</b>   | <b>v</b>    |
| <b>1.0 SUMMARY</b>   | <b>1</b>    |
| 1.1 Judgment-Analytic Critique of IPB  | 1           |
| 1.2 Aiding Judgment in IPB   | 6           |
| <b>2.0 INTELLIGENCE PREPARATION OF THE BATTLEFIELD:<br/>DEPENDENCE ON JUDGMENT</b>     | <b>13</b>   |
| 2.1 Conceptual Overview  | 13          |
| 2.2 The Role of Judgment in Each of the Five<br>IPB Steps                              | 18          |
| 2.2.1 Mission and threat evaluation  | 19          |
| 2.2.2 Tactical intelligence zone<br>determination and evaluation                       | 22          |
| 2.2.3 Terrain and weather analysis   | 23          |
| 2.2.4 Threat integration   | 25          |
| 2.2.5 Template Revision  | 28          |
| 2.3 Summary  | 33          |
| <b>3.0 POTENTIAL JUDGMENT AIDS FOR ASSISTING THE<br/>PROPOSED IPB ANALYSIS PROCESS</b> | <b>35</b>   |
| 3.1 A Multi-Attribute Utility Assessment Aid<br>for Initial Template Development       | 36          |
| 3.2 A Bayesian Aid for Template Revision   | 42          |
| 3.3 Summary  | 49          |
| <b>4.0 CONCLUSION</b>  | <b>51</b>   |
| <b>REFERENCES</b>  | <b>52</b>   |

## FIGURES

| <u>Figure</u> |   | <u>Page</u> |
|---------------|---|-------------|
| 1-1           | SCHEMATIC REPRESENTATION OF THE DYNAMIC NATURE OF THE PROPOSED IPB TEMPLATING PROCESS                           | 7           |
| 1-2           | FACTORS IN ENCOA  | 9           |
| 2-1           | PICTORIAL REPRESENTATION OF THE JUDGMENTAL NATURE OF INTELLIGENCE ANALYSIS: AN OVERVIEW                         | 14          |
| 2-2           | PICTORIAL REPRESENTATION OF THE JUDGMENTAL NATURE OF INTELLIGENCE ANALYSIS: THE UNRELIABILITY OF INFORMATION    | 15          |
| 2-3           | PICTORIAL REPRESENTATION OF THE JUDGMENTAL NATURE OF INTELLIGENCE ANALYSIS: MULTIPLE ENEMY INTENT               | 16          |
| 2-4           | SCHEMATIC REPRESENTATION OF THE DYNAMIC NATURE OF THE PROPOSED IPB TEMPLATING PROCESS                           | 30          |
| 2-5           | LENS MODEL REPRESENTATION OF JUDGMENTS INHERENT IN REVISION OF IPB TEMPLATES                                    | 32          |
| 3-1           | MULTI-ATTRIBUTE UTILITY STRUCTURE IN ENCOA FOR ASSESSING THE OVERALL VALUE OF DIFFERENT OPFOR COURSES OF ACTION | 38          |
| 3-2           | FACTORS IN ENCOA  | 39          |
| 3-3           | DECISION TREE EXAMPLE REPRESENTING THE APPLICABILITY OF EXPECTED UTILITY FRAMEWORK FOR TACTICAL DECISION MAKING | 48          |



**INTELLIGENCE PREPARATION OF THE BATTLEFIELD:  
CRITIQUE AND RECOMMENDATIONS**

**1.0 SUMMARY**

The process whereby input, new intelligence data, is translated into output, templates, necessarily depends on analysts' judgments about the implications of multiple pieces of potentially fallible data. This paper (1) provides a conceptual overview of the causal inference problem inherent in intelligence analysis, and (2) identifies the different types of judgments inherent in each of the five steps in the Intelligence Preparation of the Battlefield (IPB) analysis process proposed in Circulars TC30-27 and TC34-3. The general conclusion is that except for terrain analysis (step 3) and weather analysis (step 4), Circulars TC30-27 and TC34-3 fail to tell intelligence analysts how they are to make the judgments necessary to implement the proposed IPB analysis process. This section (1) summarizes the limitations in the other three steps of the proposed IPB analysis process, and (2) describes two judgment aids recommended for overcoming them and, thereby, improving the IPB analysis process.

**1.1 Judgment-Analytic Critique of IPB**

The purpose of mission and threat evaluation (step 1) is to review order of battle holdings so as to identify the gaps in collected intelligence data, and thereby, guide future collection efforts. Bowen, et al. (1975) point out the judgmental nature of order of battle holdings. The intelligence team must evaluate a large amount of incoming data, much of which may be unreliable, in order to decide whether it "knows" the order of battle holdings. In addition, they

must integrate the order of battle holdings, complete or not, into a judgment of enemy intent. Although the proposed IPB process uses templates to represent the output of this judgmental process, it provides no means for representing, pictorially or otherwise, the bases for the judgments underlying threat evaluation. Furthermore, TC30-27 and TC34-3 fail to provide an explicit representation of the probable relations between actual enemy intent and the order of battle holdings that represent indicators of intent; consequently, it offers no explicit rules or heuristics describing how order of battle holdings are to be combined into judgments of enemy intent. Scientific research on causal inference strongly suggests that threat evaluation judgments could be improved by providing general information about probable cause-effect relations.

Tactical intelligence zone determination and evaluation (step 2) is supposed to identify how the opposing forces (OPFOR) threat evaluated in Step 1 should look in the battlefield, in general. Circulars TC30-27 and TC34-3 accomplish this, however, only to a limited degree. There is, for example, no discussion of the general indicators for different OPFOR threats. Yet research by Johnson, Spooner, and Jaarsma (1977) suggests that this would be a valuable addition for tactical commanders. They found that a sample of forty-three captains in the Intelligence Officers Advanced Course knew only nineteen of the forty-nine separate indicators listed in Field Manual 30-5, Combat Intelligence, for four of the OPFOR threats that are to be evaluated in Step 1. TI zone determination and evaluation could be improved by indicating (1) the relative accuracy of individual indicators for different OPFOR courses of action, and (2) how to combine individual indicators into a global assessment of threat.

The objective of the fifth and final step in the proposed IPB analysis process is to relate "how the enemy would

like to fight" to a specific terrain and weather scenario as the basis for determining "how the enemy might have to fight" (TC34-3, p. 5-1). This is to be accomplished according to both circulars, through the use of situation, event, and decision support templates. These templates are proposed as a means of helping commanders "visualize" enemy capabilities in a particular combat setting. They require intelligence analysts to make a number of different kinds of judgments. Both circulars fail, however, to tell intelligence analysts how to make these judgments. These different judgments are identified below for each template, in turn. In addition, limitations in the circulars are identified, and suggestions are offered for their improvement.

The situation template shows how enemy forces probably would look within the different mobility corridors under consideration. Underlying the development of this template is a complex judgmental process. We quote TC30-27 on this point.

"While the enemy commander may not have unlimited options as to possible courses of action, he will probably have enough options to make the analyst's job of determining probable courses of action extremely difficult. Situation templates are derived based on the best military judgment of the analyst" (p. 4-4).

TC30-27 and TC34-3, however, provide only minimal information on how analysts are to exercise their "... best military judgment ..." when developing the situation templates. If the situation template is to reflect military judgment about different OPFOR courses of action, it is not enough to show analysts how to perform a terrain and weather analysis. In addition, the circulars should identify the factors that

are to be considered when making this judgment, for the analysis team will have to incorporate judgments about other, more ambiguous factors, such as perceived U.S. force strength and risk, that an OPFOR commander would certainly consider when selecting a course of action. Furthermore, the circulars should discuss the trade-offs that OPFOR commanders are likely to make when evaluating the utility of different courses of action. Rarely will it be true that one course of action is better than all others on every factor. Enemy commanders will be forced to differentially weight aspects of their doctrine with the characteristics of the situation immediately facing them. TC30-27, TC34-3, or supporting documentation should indicate what these trade-offs are likely to be under different terrain and weather constraints, if the situation template is to accurately represent military judgment under different circumstances.

"The event template is a time and logic sequence of enemy tactical indicators or events which are keyed to a series of situational templates" (TC30-27, pp. 1-6). Although TC30-27 and TC34-3 provide no example of an event template, it appears that the template must identify the different types of information necessary to confirm the adoption of a particular course of action. Such information is, in fact, required to complete the "events analysis matrix" (see TC34-3, p. 5-7). To complete this matrix, analysts must indicate those "event activities" they expect to see, as well as when and where they expect to see them, for each avenue of approach. In doing this, the analysts are essentially making a series of conditional probability judgments. That is, they must say something like, "If the enemy actually took this particular course of action, then these indicators and events have a higher probability of being observed than others." The word "probability" must be emphasized because there is not a perfect relationship between indicators,

events, and actual enemy intent. The enemy will be expected to use deceptive measures. In fact, "An integral part of templating is the consideration of deception events associated with each course of action" (TC30-27, p. 4-11). As a result, the intelligence team will be forced to make conditional probability judgments about what indicators and events they think are most indicative of the OPFOR adoption of different courses of action. Neither TC30-27 nor TC34-3, however, provide any information about the probabilistic relations between different indications and different OPFOR threats, a point made previously when discussing TI zone determination and evaluation.

The third, and final, effort in threat integration is development of a decision support template. This template "... is used to illustrate enemy probable courses of action as the basis for comparing friendly courses of action" (TC30-27, P. 4-13). Described in this way, the decision support template "... is essentially the INTELLIGENCE ESTIMATE in graphic format" (TC30-27, p. 1-6). It represents the analysts' most up-to-date estimate about the relative likelihood of the enemy's potential courses of action. Again, however, TC30-27 and TC34-3 fail to indicate how the judgments underlying this graphic representation are to be made, or in fact are made, by individual analysts. Psychological research suggests that this may result in decision support templates that (1) are not as accurate as they could be, and (2) do not facilitate communication between analysts and commanders as much as they could otherwise.

Up to this point there has been no discussion of the dynamic nature of the proposed IPB templating process. The templating process is not supposed to stop with the first support template. The decision support template at the end of one cycle of the process represents the situation template

at the beginning of the next cycle. The event template indicates the analysts' revised estimates about the likelihood of different events for different OPFOR courses of action. The event analysis matrix indicates what events were observed, when they were observed, and where they were observed during a specified time period. The decision support template represents the analysts' new judgment about the likelihood that the enemy is actually taking a particular course of action on the basis of all previous judgment and information. "Used properly, they (i.e., the templates) provide for continuing integrative analysis of OPFOR capabilities, vulnerabilities and courses of action" (TC30-27, p. 1-5). Figure 1-1 provides a schematic representation of this integrative process.

#### 1.2 Aiding Judgment in IPB

The analysis process proposed for IPB can be improved by incorporating decision-analytic techniques and computerized judgment aids. This can be accomplished because the process whereby collected intelligence data are translated into IPB templates necessarily depends on analysts' judgments about the implication of the data. Causal inference research in other settings strongly suggests that decision-analytic techniques and computerized judgment aids would improve (1) the cognitive skills and thus the judgmental accuracy of the intelligence analysts developing IPB templates, and (2) the communication process for conveying the reasons for these judgments to tactical commanders (see Adelman, Donnell, and Phelps [1981] for a review of this research). By improving the judgmental process inherent within IPB, and the means for conveying the reasons for these judgments to tactical commanders, the broader IPB analysis process should be improved in turn.

As a first step in improving the development of a decision-support (and situation) template, IPB should indicate what

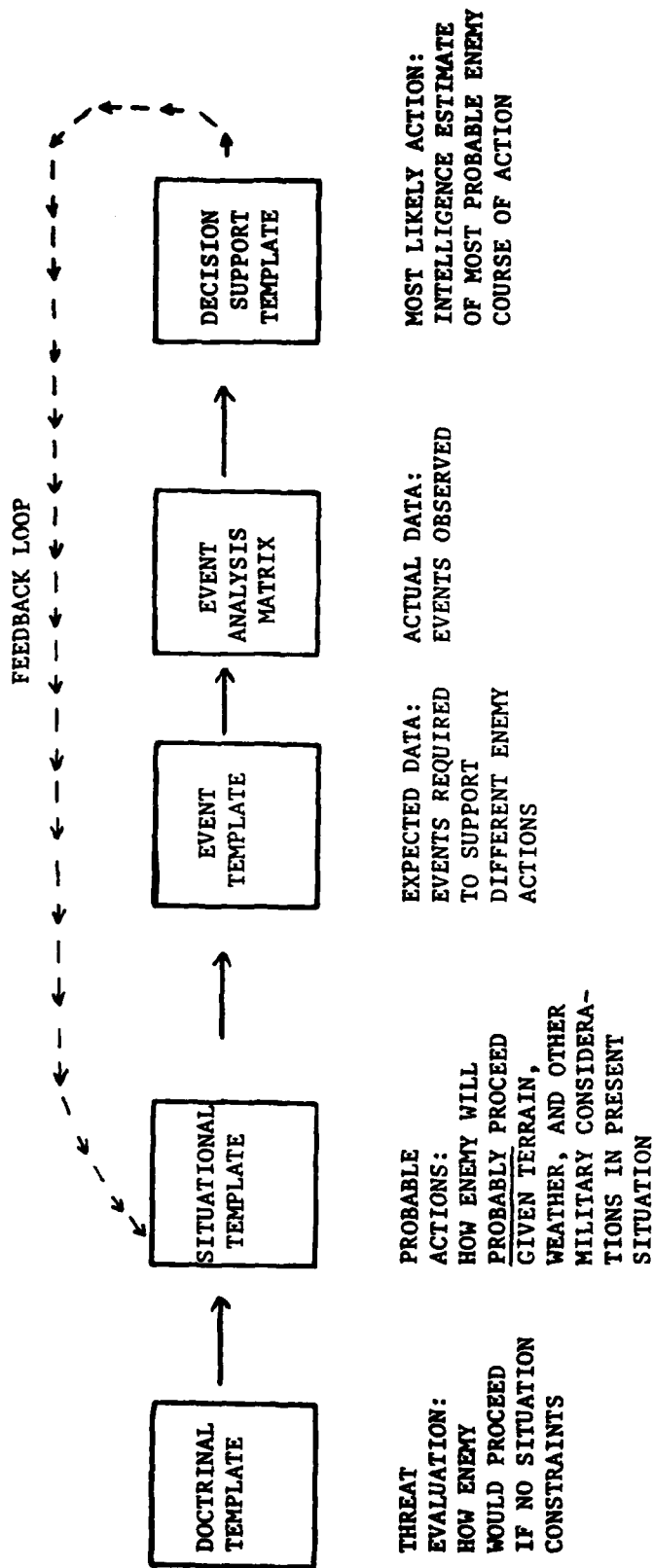


Figure 1-1

SCHEMATIC REPRESENTATION OF THE DYNAMIC NATURE OF THE PROPOSED IPB TEMPLATING PROCESS

what factors are to be taken into account when developing the decision-support template. As a second step, analysts should have access to judgment aids that help them systematically assess each potential OPFOR course of action of each of the factors. Toward this end, a prototype multi-attribute utility assessment (MAUA) aid has been developed to help intelligence analysts develop the initial decision support template (see Patterson and Phelps [1980] for a complete description). The judgment aid is called ENCOA, for Enemy Courses of Action. ENCOA provides analysts with a systematic procedure for evaluating each potential OPFOR course of action on twenty-four factors affecting enemy intent. The factors incorporated into ENCOA not only include the order of battle, terrain, and weather factors discussed in circulars TC30-27 and TC34-3, but other factors that any tactical commander would consider when selecting a course of action. These factors are grouped into the five categories indicated in Figure 1-2.

When developing the initial decision-support template, intelligence analysts can use ENCOA to assess each OPFOR course of action on each factor within the five groups of factors. Thus, each course of action would receive a score on Terrain, U.S. Force Factors, OPFOR Force Factors, Weather Factors, and Risk Factors, where the score represented the utility of the course of action to an OPFOR commander. Then, these scores can be differentially weighted to represent the trade-offs of the OPFOR commander. The scores and weights can be combined to predict the overall utility of each course of action to the OPFOR commander. In addition, ENCOA can be used to quantitatively and pictorially present the scores, weights, overall utilities, and subsequent sensitivity analyses to the friendly commander.



### I. Terrain Factors

As related to mission accomplishment and considering current OPFOR doctrine, score each OPFOR course of action in terms of how well it:

- 1.1 Exploits field of fire afforded by terrain features.
- 1.2 Exploits cover and concealment afforded by terrain features.
- 1.3 Exploits mobility provisions due to terrain features.
- 1.4 Accomplishes rapid seizure or denial of key terrain.
- 1.5 Exploits observation provisions of terrain.
- 1.6 Exploits or accommodates natural and artificial obstacles.

### II. U.S. Force Factors

As related to mission accomplishment and considering current U.S. doctrine, score each OPFOR course of action in terms of how well it exploits what you know or estimate about:

- 2.1 U.S. disposition.
- 2.2 U.S. strength and condition.
- 2.3 U.S. reserves.
- 2.4 U.S. logistic support.
- 2.5 Probable U.S. actions/reactions.
- 2.6 U.S. command and control capabilities/vulnerabilities.

### III. Opposing Force Factors

As related to mission accomplishment and considering current OPFOR doctrine, score each OPFOR course of action in terms of how well it exploits or accommodates:

- 3.1 OPFOR current disposition.
- 3.2 OPFOR strength and condition.
- 3.3 OPFOR reserves.
- 3.4 OPFOR logistic support.
- 3.5 OPFOR command and control capabilities/vulnerabilities.

### IV. Weather Factors

As related to mission accomplishment, score each OPFOR course of action in terms of how well it exploits:

- 4.1 Observation/visibility conditions forecast to exist due to weather.
- 4.2 Cover and concealment conditions forecast to exist due to weather.
- 4.3 Mobility conditions forecast to exist due to weather.
- 4.4 Effect of extreme conditions of forecast weather on personnel and equipment effectiveness.

### V. Risk Factors

As related to mission accomplishment, score each OPFOR course of action in terms of:

- 5.1 Ability to cope with surprises in terms of U.S. strength or U.S. actions/reactions.
- 5.2 Freedom from dependence on forces not under own control.
- 5.3 Freedom from critical dependence on surprise or deception.
- 5.4 Suitability under unexpected adverse weather conditions.

Figure 1-2  
FACTORS IN ENCOA

Information describing (1) how the analysts reached their conclusions about the most likely OPFOR courses of action, as well as (2) the implications of differences in opinion between the analysts, represents an important adjunct to the decision-support template.

The iterative templating process proposed in circulars TC30-27 and TC34-3 can be represented quantitatively by Bayes' Theorem, shown in equation [1].

$$\frac{P(H_1)}{P(H_2)} \times \frac{P(D|H_1)}{P(D|H_2)} = \frac{P(H_1|D)}{P(H_2|D)} \quad [1]$$

|                          |  |                              |
|--------------------------|--|------------------------------|
| (Prior<br>Probabilities) | (Conditional<br>Probabilities)                 | (Posterior<br>Probabilities) |
| Situational<br>Template  | Event Templates;<br>Event Analysis<br>Matrices | Decision<br>Templates        |

The situation template is represented by the prior probabilities, which indicate the relative likelihood of the different OPFOR courses of action (i.e., hypotheses) under consideration. The event templates and event matrices are represented by the conditional probabilities, which indicate the relative likelihood that certain events support particular courses of action. The posterior probabilities are represented by the decision support template, which indicates the revised likelihood of the courses of action (i.e., hypotheses) on the basis of observed data. This new estimate of enemy intent is then input to friendly tactical decision making and subsequent action.

Reviews of psychological research in which subjects' final probability estimates have been compared with those prescribed by Bayes' Theorem have shown consistently that humans are suboptimal processors of probabilistic information.

Although they typically revise their opinions in the same direction as Bayes' Theorem, they do not revise them enough; they are conservative. This finding could have great implications for IPB, for if analysts using IPB are conservative information processors, then they are not drawing implications from the data as fast as they could be with Bayes' Theorem. Their estimates about enemy courses of action may well be suboptimal because they will not have sufficiently revised their opinions to take full account of the certainty in the data. Consequently, the entire templating process will not convey as much information to commanders as it should. The time available for friendly tactical decision planning and implementation may be reduced considerably if intelligence analysts are conservative information processors.

General judgment aids, called Probabilistic Information Processing (PIP) systems have been developed to ensure that human judgment is consistent with Bayes' Theorem for a number of intelligence problems (e.g., see Peterson et al., 1976). Such a judgment aid is now being developed to help tactical intelligence analysts revise their judgment about the most likely OPFOR course of action on the basis of new information. The aid will probably operate in the following manner:

- (1) the analysts define the  $n$  different enemy courses of action (COAs) under consideration (i.e., enter a brief [ $\leq 10$  character title]);
- (2) the analysts enter a set of prior probabilities (or odds) for the  $n$  potential courses of action;
- (3) for a given datum, the analysts input a brief title and the probability (or odds, in terms of a likelihood ratio) of that datum conditional upon each COA being considered;

- (4) the analysts inspect the posterior probabilities (or odds);
- (5) they revise any posterior probabilities that are counter-intuitive; and
- (6) the analysts report on potential enemy COAs based on the probabilities after Step 5 or return to Step 3 if there are additional data.

The ability to use a Bayesian framework to represent the different judgments inherent in revising the IPB templates is illustrated in the above steps. Step 1 represents the different OPFOR courses of action represented in the situation template. Step 2 represents the relative likelihood of these actions at the end of one iteration of the IPB analysis process. Step 3 represents the judgments in the event templates and event matrices, which indicate the relative likelihood of having collected the newly acquired data on the basis of the enemy actually taking different courses of action. Steps 4, 5, and 6 represent the intelligence analysts' estimates of enemy intent, as represented graphically in the decision-support template.

The Bayesian aid is being designed so that it can be readily integrated into the proposed, iterative IPB analysis process. Consequently, it should help analysts implement the template revision process outlined in Circulars TC30-27 and TC34-3. The decision aid is scheduled for initial evaluation during 1981.

## 2.0 INTELLIGENCE PREPARATION OF THE BATTLEFIELD: DEPENDENCE ON JUDGMENT

### 2.1 Conceptual Overview

Figure 2-1 is a simplified representation of the judgmental nature of the intelligence process. The goal of intelligence analysis is to predict enemy intent or capability (right circle in Figure 2-1). Because the enemy intent is unknown (left circle, Figure 2-1), intelligence analysts must base their predictions on information and indicators that serve as cues to determining the unknown enemy intent. Intelligence predictions are accurate to the extent they match the unknown enemy intent as shown in Figure 2-1. Accuracy is thus a function of: (1) how reliably different cues reflect enemy intent and (2) the degree to which analysts base their predictions on the most reliable cues.

The identification and integration of these cues to form the intelligence estimate depends totally on the subjective judgment of the intelligence analyst. At a more conceptual level, the task facing intelligence analysts is one of causal inference. In fact, Figure 2-1 merely represents a minor modification of the "lens model," originally developed by Brunswik (1952, 1956), to describe pictorially the judgmental process of causal inference.

The subjective nature of intelligence analysis becomes even more obvious when more realistic representations of the intelligence process, such as those presented in Figures 2-2 and 2-3, are considered. In particular, there are three factors complicating the analyst's judgment shown in Figure 2-2. First, the relationship between the information and indicators is probabilistic; that is, indicators or information

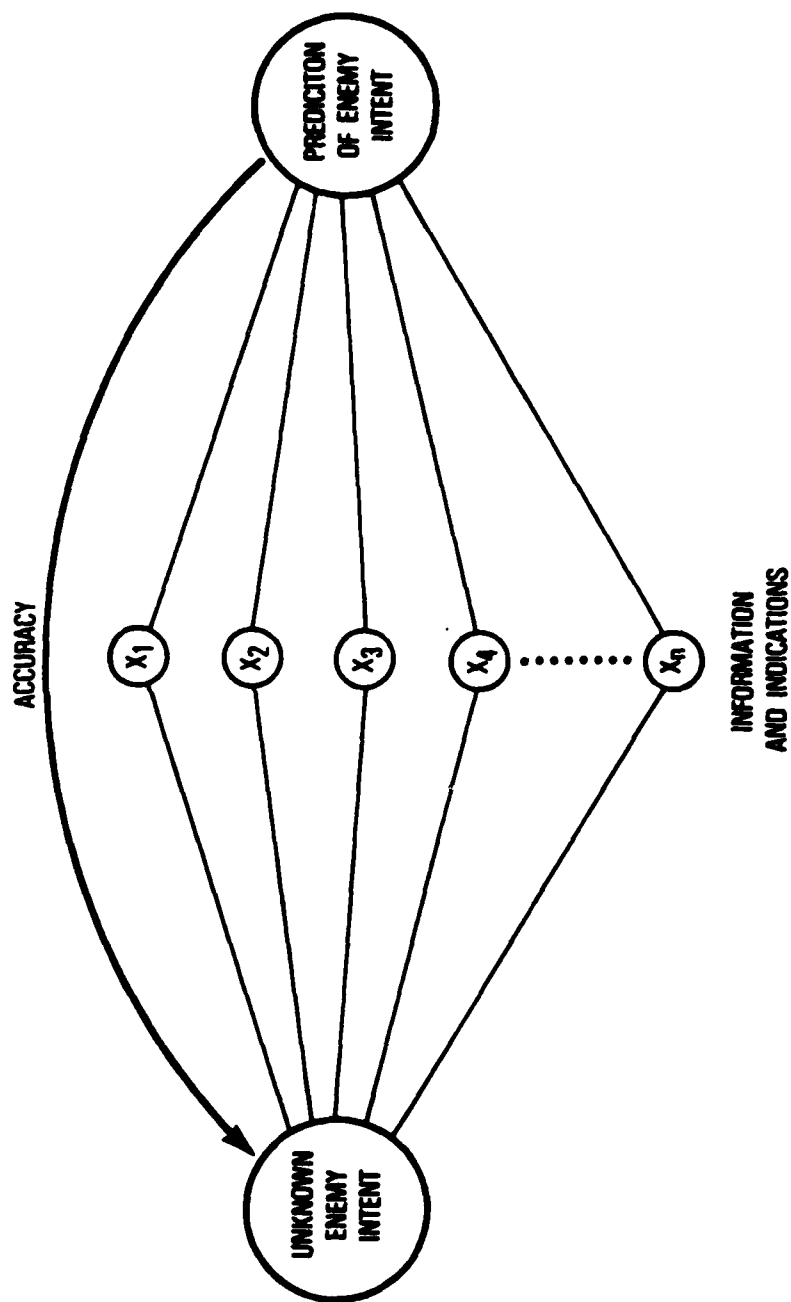


Figure 2-1  
PICTORIAL REPRESENTATION OF THE JUDGMENTAL  
NATURE OF INTELLIGENCE ANALYSIS: AN OVERVIEW

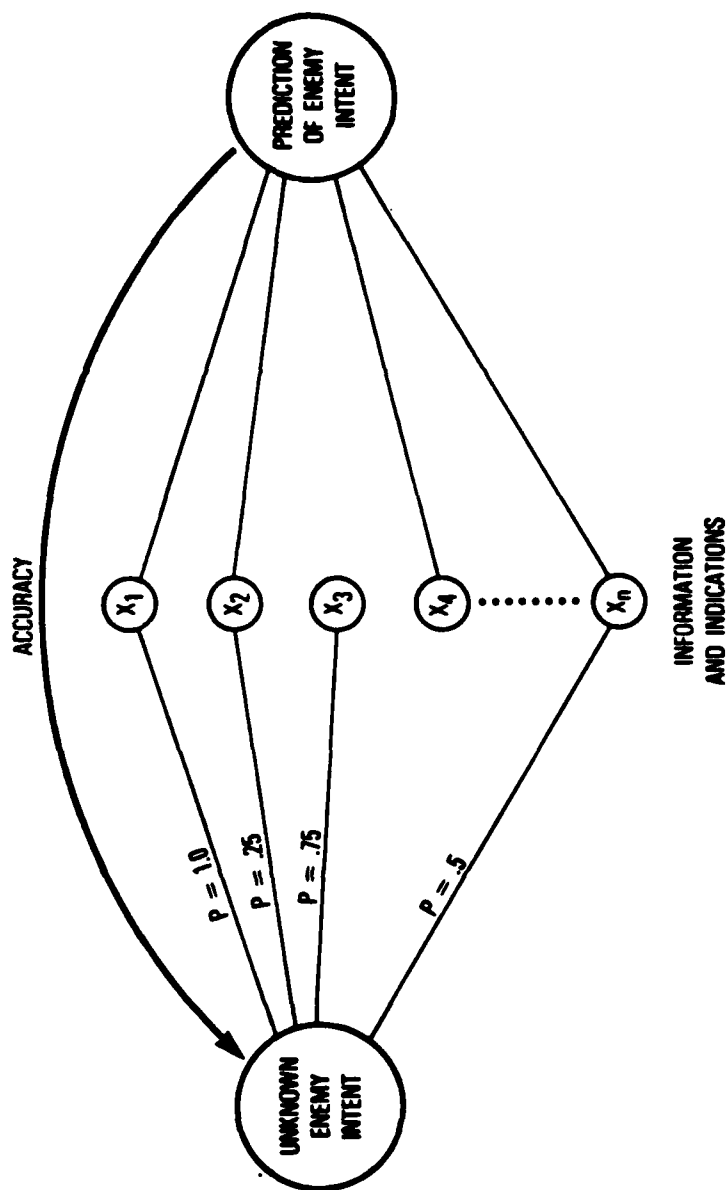


Figure 2-2  
 PICTORIAL REPRESENTATION OF THE JUDGMENTAL  
 NATURE OF INTELLIGENCE ANALYSIS: THE UNRELIABILITY OF INFORMATION

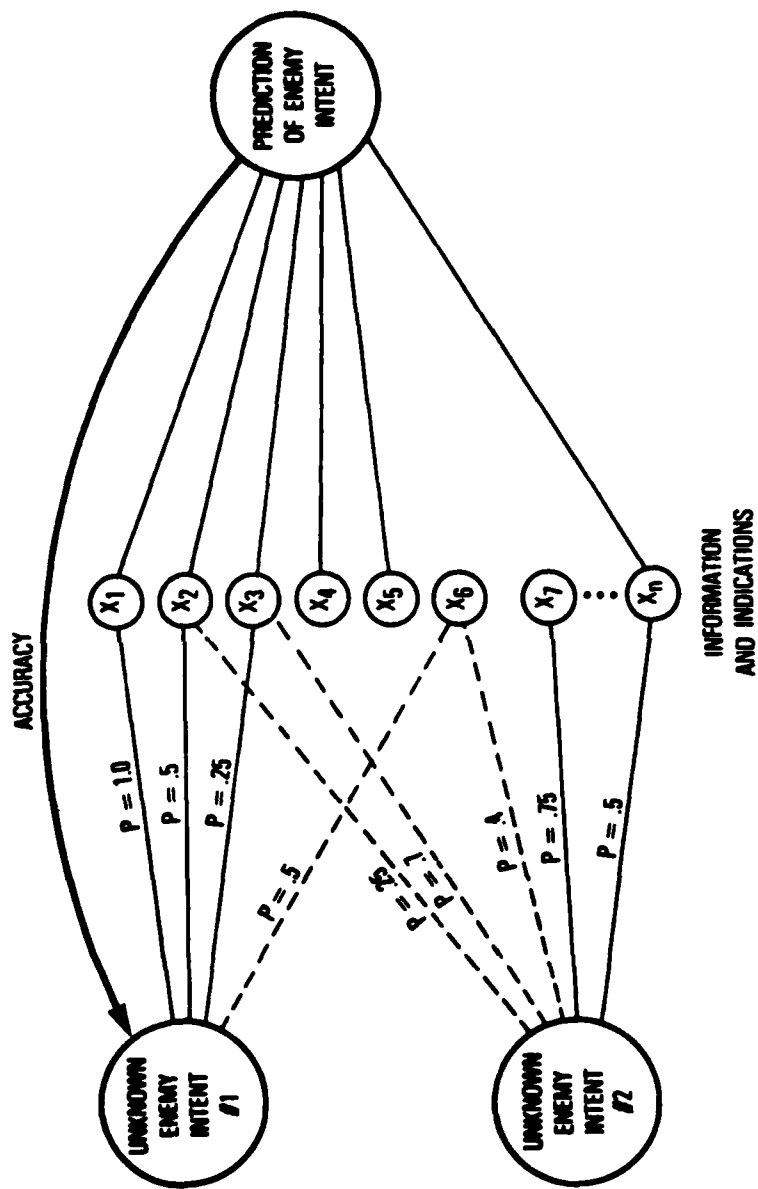


Figure 2-3  
 PICTORIAL REPRESENTATION OF THE JUDGMENTAL  
 NATURE OF INTELLIGENCE ANALYSIS: MULTIPLE ENEMY INTENT



correspond to enemy intent less than 100% of the time, causing the indicators to vary in reliability. Second, intelligence analysts may fail to use reliable indicators. Third, some information, not related to the enemy intent, may influence the analyst's prediction. Analysts must be able to perceive the relative reliability of indicators and be able to use only the most reliable ones in their analysis, ignoring the unreliable indicators.

Indicator unreliability is compounded when the indicators are related to more than one enemy intent as depicted in Figure 2-3. For example, some indicators can be used to predict two or more enemy intentions, such as attack and delay. As a result, the analyst must juggle the relative reliability of the indicators in order to predict the relative likelihood of the possible enemy intentions. The more ambiguous or unreliable the indicators and information, the more the accuracy of the prediction depends on the subjective judgment of the intelligence analyst.

Intelligence Preparation of the Battlefield, as described in Circulars TC30-27 (1978) and TC34-3 (in preparation), represents a major step toward improving procedures for correlating data with enemy intent. This is to be accomplished through "templating," using a series of graphic illustrations of an enemy capability drawn as an overlay over a map. The process whereby input, new intelligence data, is translated into output, templates, necessarily depends on analysts' judgments about the implications of multiple pieces of potentially fallible data, as represented pictorially in Figures 2-1, 2-2, and 2-3. TC30-27 and TC34-3 however, provide little information about how intelligence analysts should make these judgments. This omission may limit the usability and accuracy of IPB as it is proposed in these circulars, for scientific research strongly suggests that the kinds of complex causal inferences required in intelligence analysis tend not to be as accurate as they

could be without explicit training about the relationships between information and enemy intent. Furthermore, the research suggests that systematic, decision-analytic techniques and computerized decision aids would improve both (1) the judgmental skills of intelligence analysts developing IPB templates, and (2) the communication process for conveying the reasons for these judgments to tactical commanders. By improving the judgmental process inherent within IPB, and the means for conveying the reasons for these judgments to tactical commanders, the broader IPB analysis process would be improved in turn.

This paper describes the necessary dependence of IPB on human judgment. It is part of a larger paper directed toward evaluating the applicability of different areas of decision research, different decision-analytic techniques, and different types of computerized decision aids to IPB. The larger paper is technically oriented and written primarily for judgment researchers working with analysts in the intelligence community. This paper, in contrast, is written at a more general level, and for intelligence analysts, particularly those developing IPB. Organizationally, it first identifies the different types of judgment inherent in each of the five steps in the IPB analysis process proposed in Circulars TC30-27 and TC30-3; limitations in the proposed IPB analysis process are identified by doing so. Second, Section 3.0 describes two decision aids for overcoming these limitations and, thereby, improving the IPB analysis process.

## 2.2 The Role of Judgment in Each of the Five IPB Steps

"IPB is a continuous process of analysis and evaluation which is the basis of intelligence operations planning.... The purpose of this analysis is to determine and evaluate enemy capabilities, vulnerabilities, and courses of action as the basis for friendly operations planning" (TC30-27, p.iii). To accomplish this purpose, the following five steps in IPB analysis are proposed in TC30-27: (1) mission

and threat evaluation, (2) TI zones determination and evaluation, (3) terrain analysis, (4) weather analysis, and (5) threat integration. The next section of this report is directed toward identifying the different types of judgment inherent in each of these five steps, in turn.

2.2.1 Mission and threat evaluation - This is the first step of the proposed IPB analysis process. Mission evaluation establishes the area of operation and identifies the general battlefield scenario. Threat evaluation of doctrine, tactics, capabilities, and equipment includes a review of the following order of battle intelligence holdings: composition, disposition, strength, tactics, training, logistics, and combat effectiveness. The purpose of this review is to identify the gaps in collected intelligence data and, thereby, guide future collection efforts.

Opposing force (OPFOR) doctrine is to serve as the basis for knowing and understanding the potential adversary and, therefore, implementing mission and threat evaluation. Intelligence analysts are to develop "doctrinal templates" that indicate how the enemy likes to fight. Figure 1 in TC34-3, for example, shows a doctrinal template for a motorized rifle regiment in movement to contact. Intelligence analysts and tactical commanders "seeing" an OPFOR motorized rifle regiment in this disposition, therefore, should conclude that the enemy's intent is to attack.

The doctrinal template thus represents a standard against which order of battle holdings, such as disposition, can be reviewed. If the intelligence team does not know, for the above example, the disposition, composition, or combat effectiveness of the OPFOR motorized rifle regiment in the area of operation, then intelligence data must be collected on the missing order of battle holdings. Once the data is collected, the team can convey their evaluation of OPFOR

threat to the commander in the form of a template or otherwise. What Circulars TC30-27 and TC34-3 fail to point out, however, is that the review of order of battle holdings is a complex judgmental process. The intelligence team must evaluate a large amount of incoming data, much of which may be unreliable, in order to decide whether it "knows" the order of battle holdings. In addition, they must integrate the order of battle holdings, complete or not, into a judgment of enemy intent.

The judgmental nature of order of battle holdings is noted clearly by Bowen, Halpin, Russell, and Staniforth (1975) in Tactical Order of Battle: A State of the Art Survey. Judgment is required because there is simply no alternative to it. We quote Bowen, et al. (1975, p. 45) on this point:

"Each OB Factor is defined in terms of a number of information elements which indicate the kind of data required to describe the status of that factor in narrative terms. No specific rules exist, either formal or heuristic, for the evaluation of factors or elements, or their combination."

In fact, the lack of "specific rules," or in terms of IPB, "templates," for making Order of Battle judgments is represented in each of the following "key problems" identified by Bowen et al. (1975, pp. 59-60):

- "1. There are no standardized methodologies for estimating OB factors....
2. There are no standardized methodologies for incorporating OB factors into the products of OB intelligence.

3. There is no methodology for estimating and reporting reliabilities of OB factor estimates nor the significance of levels of OB factors and their elements relative to general descriptors of the state of enemy forces, such as Combat Effectiveness.
4. There is no realistic and generally accepted definition of the OB factor of Combat Effectiveness. A serious ambiguity of rationale about estimating enemy Combat Effectiveness derives from the point of view of the estimator. (A G2 thinks in terms of the enemy force, while the commander of G3 is concerned with the enemy's net potential effectiveness relative to friendly forces in the existing circumstances.)
5. There is no indication in doctrine of the relative importance of the OB factors, or of their inter-relationships.
6. There are no consistent, validated indicators, data aggregates, or data elements for the various OB factors and their elements.
7. There is no methodology for relating the elements of an OB factor to each other, or to the factor itself."

Nor does TC30-27 or TC34-3 offer a "methodology" for making the judgment inherent in threat evaluation. Intelligence analysts are still on their own to combine data on order of battle holdings as they see fit. And, as point #4 above notes, different analysts might combine the data differently. While the proposed IPB analysis may use templates to represent the output of this judgmental process,

it provides no means for representing, pictorially or otherwise, the basis for the judgments underlying threat evaluation. In terms of Figure 2-2, for example, TC30-27 and TC34-3 fail to provide an explicit representation of the probable relations between actual enemy intent and the order of battle holdings that represent indicators of intent ( $X_1$ ); consequently, it offers no explicit rules or heuristics describing how order of battle holdings ( $X_1$ ) are to be combined into judgments of enemy intent. Scientific research on causal inference indicates that the accuracy of causal inferences can be improved by providing information about probable cause-effect relations represented on the left side of the model in Figure 2-2.

2.2.2 Tactical intelligence zone determination and evaluation - This is the second step in the proposed IPB analysis process. Circular TC30-27 proposes three TI zones to help the commander at the company, battalion/brigade, and corps/division levels, respectively, "... SEE the battlefield" (TC30-27, p. 27). For, according to TC30-27, it is the intelligence analyst's job to make sure that commanders know what the intelligence collection and processing system can and cannot do prior to combat. Toward that end, TI zone determination and evaluation is proposed as a means of telling commanders where to look for targets and indicators of activities that confirm the enemy's adoption of a course of action; what to look for, that is, the critical indicators that must be seen by a certain time; when in the battle sequence to look for them; and what data collection tools to look with. Circular TC34-3 also emphasizes these points, but refers to the TI zones as "areas of interest/influence" (see Chapter 3).

Step 2, therefore, is supposed to identify how the OPFOR threat evaluated in Step 1 should look in the battlefield, in general. Circulars TC30-27 and TC34-3

accomplish this, however, only to a limited degree. There is, for example, no discussion of the general indicators for different OPFOR threats. Yet research by Johnson, Spooner, and Jaarsma (1977) suggests that this would be a valuable addition for tactical commanders. They found that a sample of forty-three captains in the Intelligence Officers Advanced Course knew only nineteen of the forty-nine separate indications listed in Field Manual 30-5, Combat Intelligence, for the four separate courses of action to be evaluated in Step 1: attack, defense, delay, and withdrawal.

Just as in the case of threat evaluation, the judgmental conceptualizations shown in Figures 2-1, 2-2, and 2-3 represent the basic judgment problem facing analysts during TI zone evaluation. Doctrinal templates could be developed to help commanders visualize the general indicators representative of different OPFOR threats at different TI zones. In addition, decision aids could be developed to assist in TI zone evaluation. Since individual indications are not perfect predictors of enemy intent, analysts and commanders must know the relative accuracy of individual indicators for each of the different OPFOR courses of action. Furthermore, they must know how to combine individual indicators into a global assessment of threat. TC30-27 provides no indication of how this is to be accomplished in TI zone evaluation. Causal inference research indicates that explicit information about the left-hand side of the causal inference represented in Figures 2-1, 2-2, and 2-3 greatly improves the judgmental accuracy of individuals.

2.2.3 Terrain and weather analysis - It is interesting to note that Circulars TC30-27 and TC34-3 do tell analysts how to make judgments about the military aspects of terrain and weather, the third and fourth steps, respectively, in the proposed IPB analysis process. The determination of avenues

of approach into the commander's TI zone is basic to terrain analysis. To accomplish this, the IPB analysis team must focus its analytical efforts on the following five military aspects of terrain: observation in fields of fire, concealment and cover, obstacles, key terrain, and avenues of approach. Toward this end, the circular contains a factor and subfactor analysis matrix, and a list of terrain requirements. This information defines the relationships between the physical aspects of terrain, such as surface configuration, vegetation, rock types and soils, and specific military aspects of terrain, such as observation and fields of fire, cover, concealment, and obstacles. Thus, it shows the analysts how to make judgments about the military aspects of terrain. Such analytical efforts facilitate subsequent "mobility analysis" and "line-of-sight analysis," the result of which is a series of map overlays that identify the possible OPFOR avenues of approach and the ... "one avenue of approach (mobility corridor) more favorable than the others" (TC30-27, p. 3-26). They also provide a retraceable procedure for telling the commander how these judgments were arrived at by the analysts.

As in the case of terrain analysis, the IPB analysis process addresses the effects of weather on ground and air mobility and line-of-sight. In a similar fashion, Circulars TC30-27 and TC34-3 address in considerable detail how the "weather factor analysis matrix" and "weather parameter-user matrix" are to be used to relate weather factors to a wide range of military operations. The result of Step 4 is a set of overlays that integrate terrain and weather data in a manner that conveys their possible interactive effects on the capability of forces to move, shoot and communicate within the different mobility corridors in the situation under consideration. The word "possible" is underlined to emphasize the uncertain nature of weather; the



best mobility corridor if it's dry can be the worst one if it rains.

2.2.4 Threat integration - This is the fifth and final step in the proposed IPB analysis process. The objective of threat integration is to relate "how the OPFOR likes to fight" to a specific terrain and weather scenario as the basis for determining "how the enemy might have to fight" (TC34-3, p. 5-1). This is to be accomplished through the use of situation, event, and decision support templates. These templates are proposed as a means of helping commanders "visualize" enemy capabilities in a particular combat setting. They require intelligence analysts to make a number of different kinds of judgments. Both circulars fail, however, to tell intelligence analysts how to make these judgments. These different judgments are identified below for each template, in turn. In addition, limitations in the circulars are identified, and suggestions are offered for their improvement.

The situation template shows how enemy forces probably would look within the different mobility corridors under consideration. The analysts developing the situation template, therefore, must use the terrain and weather analyses to modify the doctrinal templates for the OPFOR threat evaluated in step #1. Underlying the development of this template is a complex judgmental process. We quote TC30-27 on this point.

"While the enemy commander may not have unlimited options as to possible courses of action, he will probably have enough options to make the analyst's job of determining probable courses of action extremely difficult. Situation templates are derived based on the best military judgment of the analyst (p. 4-4)."

Unfortunately, TC30-27 provides minimal information on how analysts are to exercise their "... best military judgment ..." when developing the situation templates. In fact, it does not even identify the factors that are to be considered explicitly when making their judgments.

If the situation template is to reflect military judgment about different OPFOR courses of action, it is not enough to show analysts how to perform a terrain and weather analysis. In addition, Circulars TC30-27 and TC34-3 should identify the factors that are to be considered when making this judgment, for the analysis team will have to incorporate judgments about other, more ambiguous factors, such as perceived U.S. force strength and risk, that an OPFOR commander would certainly consider when selecting a course of action. Furthermore, the circulars should discuss the trade-offs that OPFOR commanders are likely to make when evaluating the utility of different courses of action. Rarely will it be true that one course of action is better than all others on every factor. Enemy commanders will be forced to differentially weight aspects of their doctrine with the characteristics of the situation immediately facing them. Circulars TC30-27 and TC34-3, or supporting documentation, should indicate what these trade-offs are likely to be under different terrain and weather constraints, if the situation template is to accurately represent military judgment under different circumstances. Said differently, it should describe the left side of the lens model in Figure 2-1, which describes how the enemy tends to make judgments of intent.

"The event template is a time and logic sequence of enemy tactical indicators or events which are keyed to a series of situational templates." (TC30-27, pp. 1-6). This is to be accomplished by identifying, on the situation

template, "NAMED AREAS OF INTEREST (NAI's)... along each route where the analyst expects to see certain events or activities occur" (TC30-27, p. 4-4). In addition, the analyst is to complete an event analysis matrix that "... correlates WHAT IS EXPECTED (event/activity) to the WHERE and WHEN (Geographical coordinates and time)" (TC30-27, p. 4-6). The event template is to be a combination of the situation template and the event analysis matrix.

Although TC30-27 and TC34-3 provide no example of an event template, it appears that the template must identify the different types of information necessary to confirm or deny the adoption of a particular course of action. To accomplish this, the analysts must make a series of conditional probability judgments analogous to those represented in Figures 2-2 and 2-3. That is, they must say, "If the enemy actually took this particular course of action, then these indicators, and events (e.g.,  $X_2$ ) have a higher probability of being observed than others." The word "probability" must be emphasized because there is not a perfect relationship between indicators, events, and actual enemy intent. The enemy will be expected to use deception measures. In fact, "An integral part of templating is the consideration of deception events associated with each course of action" (TC30-27, p. 4-11). As a result, the intelligence team will be forced to make conditional probability judgments about what indicators and events they think are most indicative of the OPFOR adoption of different courses of action. Neither TC30-27 nor TC34-3 provides any information about the probabilistic relations between different indications and different OPFOR threats, a point made previously in the discussion of TI zone determination and evaluation.

The third, and final, effort in threat integration is development of a decision support template. This

template "... is used to illustrate enemy probable courses of action as the basis for comparing friendly courses of action" (TC30-27, p. 4-13). Described in this way, the decision support template "... is essentially the INTELLIGENCE ESTIMATE in graphic format" (TC34-3, p. 5-10). It represents the analysts' most up-to-date estimate about the relative likelihood of the enemy's potential courses of action. Again, however, TC30-27 and TC34-3 fail to indicate how the judgments underlying their graphic representation are to be made, or in fact are made, by individual analysts. In terms of Figure 2-1, they fail to describe the right side of the lens model, the reasons for judgments of enemy intent. Psychological research suggests that this may result in decision support templates that (1) are not as accurate as they could be, and (2) do not facilitate communication between analysts and commanders as much as they could otherwise.

2.2.5 Template Revision - Up to this point, there has been no discussion of the dynamic nature of the proposed IPB templating process. The templating process is not supposed to stop with the first decision-support template. "They are to be changed, deleted, or redone as conditions and situations demand. Used properly, they provide for continuing integrative analysis of OPFOR capabilities, vulnerabilities and courses of action" (TC30-27, p. 1-5). This iterative revision process is critical to friendly tactical decision making. Friendly commanders will make particular decisions, and take subsequent actions, on the basis of intelligence analysts' estimate of enemy intent. This estimate will be revised continuously upon the arrival of new information. The faster the information can be correlated with enemy intent, the more time friendly commanders will have for tactical decision making and action.

Template revision is represented pictorially in Figure 2-4. Notice that the decision support template at the end of one cycle of the process is the situation template at the beginning of the next cycle. The event template indicates the analysts' revised estimates about the likelihood of different events for different OPFOR courses of action. The event analysis matrix indicates what events were observed, when they were observed, and where they were observed during a specified time period. The decision support template represents the analysts' new judgment about the likelihood that the enemy is actually taking a particular course of action on the basis of all previous judgment and information.

The dynamic nature of the proposed templating process is heavily dependent on a complex judgment process. First, intelligence analysts using the proposed IPB analysis process must identify the initial hypotheses regarding possible enemy courses of action and, if possible, an initial estimate of the most probable course of action. As discussed above, this requires consideration of how the enemy generally makes judgments of intent, in addition to an evaluation of how physical terrain and weather factors favor different courses of action.

Second, intelligence analysts using the proposed IPB process must indicate the events that are likely to be observed for each course of action. The information within each event template represents, in qualitative or intuitive terms, conditional probabilities. If the enemy actually took a particular course of action, then certain events have a higher probability of being observed than others. The information within all the event templates represents, again in qualitative terms, likelihood ratios that indicate how much more likely certain events are to be observed for one course of action than another. While these probabilistic

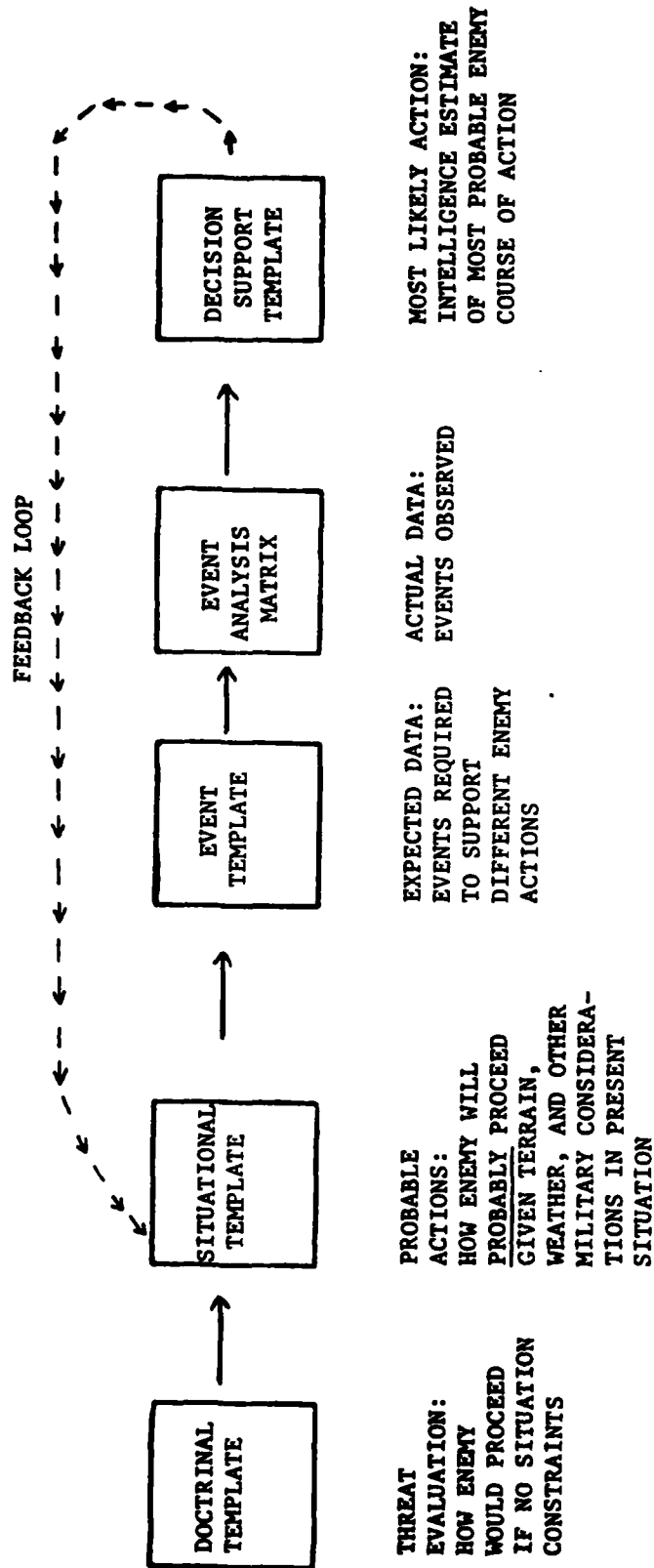


Figure 2-4

SCHEMATIC REPRESENTATION OF THE DYNAMIC NATURE  
OF THE PROPOSED IPB TEMPLATING PROCESS

judgments are not being made quantitatively when analysts develop the event templates, they are being made intuitively in order to guide data collection in an uncertain environment.

Third, the analysts must use the many pieces of potentially fallible data reported in the event matrices (and other sources) to revise their initial hypotheses about the enemy's most likely course of action. The data reported in the event matrices also represent conditional probabilities, for certain events have a higher probability of being observed only when the enemy is actually taking a particular course of action. As a result, subsequent decision support templates represent, again in qualitative terms, the analysts' most up-to-date estimate about enemy intent, as revised by newly acquired intelligence data.

The three areas of judgment inherent in the revision process can be represented conceptually by the modified lens model shown in Figure 2-5. The situation template indicates the analysts' military judgment about the likelihood of different enemy courses of action. The event templates indicate events the analysts expect to see in support of each course of action. The event analysis matrices indicate the events subsequently reported in intelligence data. The events "seen" are matched with those "expected" in order to develop a revised estimate of enemy intent, which is represented in the decision support template. The decision support template is now the situation template for the next iteration.

There are different ways to represent quantitatively the three areas of judgment inherent in the template revision process. These procedures will be considered in some detail in the next section when we consider different decision aids for supplementing, and thereby improving the proposed IPB analysis process. Suffice it to say for now, that these procedures often rely on the principle of divide

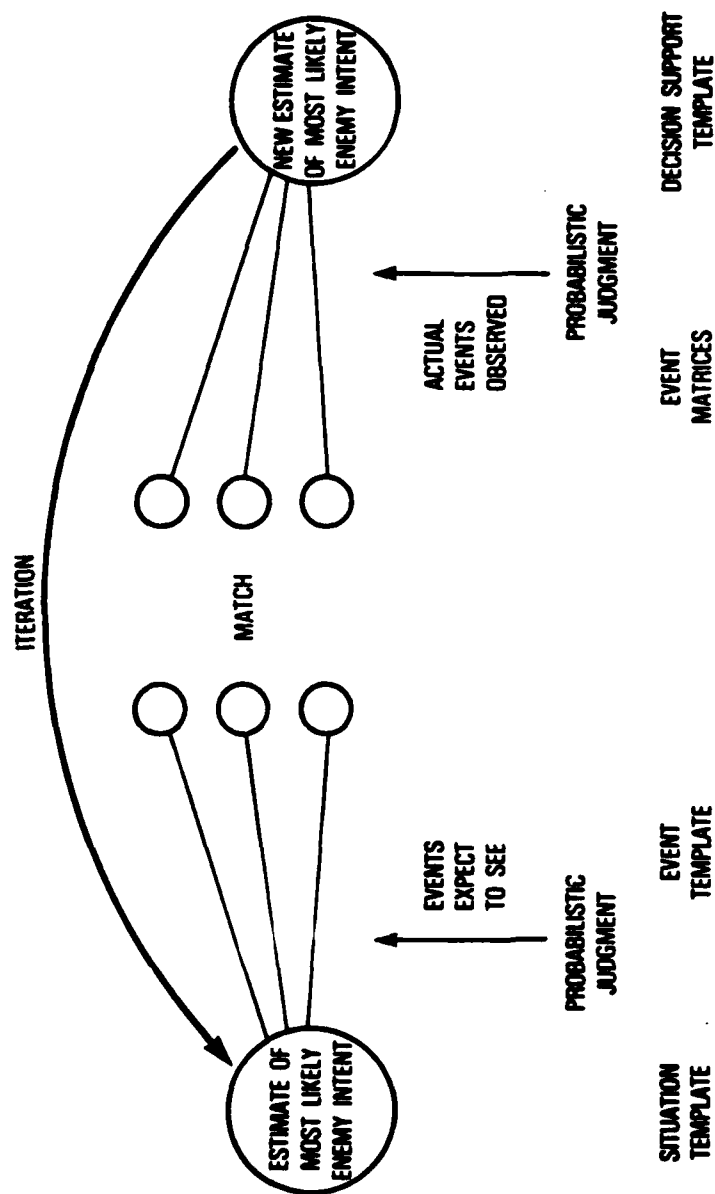


Figure 2-5  
LENS MODEL REPRESENTATION OF JUDGMENTS  
INHERENT IN REVISION OF IPB TEMPLATES



and conquer. First, the total problem is divided into a series of structurally related parts. The intelligence analyst is asked to evaluate each OPFOR alternative under consideration for each of the independent, simpler components that comprise the larger intelligence problem. Then, computerized judgment aids combine all the judgments in order to provide an overall evaluation of each alternative. Many of the aids also provide sensitivity analysis, thereby permitting intelligence analysts to observe the effects of changing their judgments on the overall score for each alternative. Thus, decision-analytic techniques and computerized aids "conquer" the global decision problem by providing an analytical means of expanding the intelligence analyst's cognitive skills.

### 2.3 Summary

The purpose of IPB is to improve procedures for correlating data with enemy intent. This purpose is to be accomplished by templating, an analytical tool designed to help analysts and commanders visualize the battlefield. While important, this advance does not go far enough, for it fails to make explicit how input, new intelligence data (Xi), is to be converted into output, templates. This translation process necessarily depends on judgment. However, Circulars TC30-27 and TC34-3 provide practically no information about how these judgments are to be made by analysts.

Section 2.0 described the necessary dependence of IPB on human judgment. In particular, it provided a conceptual overview of the causal inference problem inherent in intelligence analysis, and identified the different types of judgment inherent in each of the five steps in the IPB analysis process proposed in Circulars TC30-27 and TC34-3. The general conclusion was that except for terrain analysis (Step 3) and weather analysis (Step 4), these circulars fail to tell intelligence analysts how they are to make the

judgments necessary to implement the proposed IPB analysis process. The lack of, and need for, procedures for helping analysts make the judgments in the other three steps of the proposed IPB analysis process were discussed at length.

It is important to note that the proposed IPB analysis process is a dynamic one, for the decision-support template at the end of one cycle of the process is the situation template at the beginning of the next cycle. Three areas of judgment are inherent in the revision process. These areas of judgment were represented conceptually within the causal inference model presented in Section 2.0. Analytical procedures and computerized judgment aids for assisting analysts tasked with making these, and the other judgments in the proposed IPB analysis process, are described in Section 3.0.

### 3.0 POTENTIAL JUDGMENT AIDS FOR ASSISTING THE PROPOSED IPB ANALYSIS PROCESS

The analysis process proposed for IPB can be improved by incorporating decision-analytic techniques and computerized judgment aids. This can be accomplished because the process whereby collected intelligence data is translated into IPB templates necessarily depends on analysts' judgments about the implication of the data. Causal inference research in other settings strongly suggests that decision-analytic techniques and computerized judgment aids would improve (1) the cognitive skills and, thus, the judgmental accuracy of intelligence analysts developing IPB templates, and (2) the communication process for conveying the reasons for these judgments to tactical commanders. By improving the judgmental process inherent within IPB, and the means for conveying the reasons for these judgments to tactical commanders, the broader IPB analysis process should be improved in turn.

This section is divided into two parts. The first part describes a judgment aid utilizing multi-attribute utility assessment (MAUA) concepts. The second part describes a Bayesian judgment aid. Utilization of MAUA aids is described primarily within the context of developing the initial decision-support template. Utilization of Bayesian aids is described primarily within the context of revising decision support templates on the basis of newly collected data represented in the event templates and event analysis matrices. These differences in emphasis are used here to indicate the strengths of each class of judgment aid; however, both types of judgment aid can be used in initial development and subsequent revision of decision support templates.

### 3.1 A Multi-Attribute Utility Assessment Aid for Initial Template Development

As a first step in improving the development of a decision-support (and situation) template, IPB should indicate what factors are to be taken into account when developing the decision-support template. As a second step, analysts should have access to judgment aids that help them systematically assess each potential OPFOR course of action on each of the factors. Toward this end, a prototype multi-attribute utility assessment (MAUA) aid has been developed to help intelligence analysts develop the initial decision-support template; see Patterson and Phelps (1980) for a complete description. The judgment aid is called ENCOA, for Enemy Courses of Action. ENCOA provides analysts with a systematic procedure for evaluating each potential OPFOR course of action on twenty-four factors affecting enemy intent.

The utilization of ENCOA, like all MAUA-based decision aids, requires five basic steps. First one develops a hierarchy of attributes (or criteria) that structure the process of evaluating the different alternatives. Second, one scores each of the alternatives on each of the attributes at the bottom of the hierarchy. Third, one specifies the relative importance (or weight) of the multiple attributes within each level of the hierarchy. Fourth, one combines the scores (step #2) and relative weights (step #3) to obtain an overall value for each alternative. Fifth, one performs sensitivity analyses to determine what conditions will change the conclusion of the MAUA effort. Each step is considered below at a general level and for ENCOA in particular.

A MAUA model is hierarchical in nature, starting with the specified top-level factor for which an overall score is

desired. This factor is successively decomposed into subfactors in descending levels of the hierarchy such that each successive level is more specific than the one preceding. At the lowest level of the hierarchy are predictable or highly observable characteristics of the alternatives under evaluation.

Figure 3-1 shows the MAUA hierarchy in ENCOA for assessing the overall utility (or value) of the different courses of action open to OPFOR commanders. There are five major factors for evaluating the overall utility of each alternative: Terrain, U.S. Forces, OPFOR Forces, Weather, and Risk. Each of these higher level factors is decomposed into more observable subfactors. Figure 3-2 provides the definitions for these lower level subfactors. These subfactors are defined in a manner that permits intelligence analysts to score each alternative on each subfactor, the second step in using ENCOA.

ENCOA uses a relative scoring system. The best OPFOR course of action on each subfactor is given a score of 100, the worst OPFOR course of action on that subfactor is given a 0, and other courses of action are given intermediate values between 100 and 0 relative to the best and worst alternatives, respectively. A relative scoring system is used instead of an absolute scoring system because of the difficulty, if not the impossibility, of trying to define a true zero level on each subfactor. An absolute scoring system necessitates defining a true zero level of performance and then scoring systems proportional to how far they exceed that zero level; a "relative" scoring system arbitrarily selects the least desirable outcome on each criterion as a relative zero, and then scores each of the other systems proportional to the magnitude of the difference between that system and the one with the lowest score. A relative scoring system is used in ENCOA because of the

| <u>FACTOR CATEGORY</u>       |                         | <u>FACTOR</u>                            |
|------------------------------|-------------------------|--|
| 0. Mission<br>Accomplishment | 1.0 Terrain Factors     | 1.1 Fields of Fire                       |
|                              |                         | 1.2 Cover and Concealment                |
|                              |                         | 1.3 Mobility                             |
|                              |                         | 1.4 Seize/Deny Key Terrain               |
|                              |                         | 1.5 Observation                          |
|                              |                         | 1.6 Natural/Artificial Obstacles         |
|                              | 2.0 U.S. Force Factors  | 2.1 Disposition                          |
|                              |                         | 2.2 Strength and Condition               |
|                              |                         | 2.3 Reserves                             |
|                              |                         | 2.4 Logistic Support                     |
|                              |                         | 2.5 Probable Actions/Reactions           |
|                              |                         | 2.6 Command and Control                  |
|                              | 3.0 OPFOR Force Factors | 3.1 Current Disposition                  |
|                              |                         | 3.2 Strength and Condition               |
|                              |                         | 3.3 Reserves                             |
|                              |                         | 3.4 Logistic Support                     |
|                              |                         | 3.5 Command and Control                  |
|                              | 4.0 Weather Factors     | 4.1 Observation/Visibility               |
|                              |                         | 4.2 Cover and Concealment                |
|                              |                         | 4.3 Mobility                             |
|                              |                         | 4.4 Extreme Weather Effects              |
|                              | 5.0 Risk Factors        | 5.1 U.S. Actions/Reactions               |
|                              |                         | 5.2 Dependence on Other Commands         |
|                              |                         | 5.3 Dependence on Surprise/<br>Deception |
|                              |                         | 5.4 Unexpected Weather                   |

Figure 3-1

MULTI-ATTRIBUTE UTILITY STRUCTURE IN ENCOA FOR  
ASSESSING THE OVERALL VALUE OF DIFFERENT  
OPFOR COURSES OF ACTION

### I. Terrain Factors

As related to mission accomplishment and considering current OPFOR doctrine, score each OPFOR course of action in terms of how well it:

- 1.1 Exploits field of fire afforded by terrain features.
- 1.2 Exploits cover and concealment afforded by terrain features.
- 1.3 Exploits mobility provisions due to terrain features.
- 1.4 Accomplishes rapid seizure or denial of key terrain.
- 1.5 Exploits observation provisions of terrain.
- 1.6 Exploits or accommodates natural and artificial obstacles.

### II. U.S. Force Factors

As related to mission accomplishment and considering current U.S. doctrine, score each OPFOR course of action in terms of how well it exploits what you know or estimate about:

- 2.1 U.S. disposition.
- 2.2 U.S. strength and condition.
- 2.3 U.S. reserves.
- 2.4 U.S. logistic support.
- 2.5 Probable U.S. actions/reactions.
- 2.6 U.S. command and control capabilities/vulnerabilities.

### III. Opposing Force Factors

As related to mission accomplishment and considering current OPFOR doctrine, score each OPFOR course of action in terms of how well it exploits or accommodates:

- 3.1 OPFOR current disposition.
- 3.2 OPFOR strength and condition.
- 3.3 OPFOR reserves.
- 3.4 OPFOR logistic support.
- 3.5 OPFOR command and control capabilities/vulnerabilities.

### IV. Weather Factors

As related to mission accomplishment, score each OPFOR course of action in terms of how well it exploits:

- 4.1 Observation/visibility conditions forecast to exist due to weather.
- 4.2 Cover and concealment conditions forecast to exist due to weather.
- 4.3 Mobility conditions forecast to exist due to weather.
- 4.4 Effect of extreme conditions of forecast weather on personnel and equipment effectiveness.

### V. Risk Factors

As related to mission accomplishment, score each OPFOR course of action in terms of:

- 5.1 Ability to cope with surprises in terms of U.S. strength or U.S. actions/reactions.
- 5.2 Freedom from dependence on forces not under own control.
- 5.3 Freedom from critical dependence on surprise or deception.
- 5.4 Suitability under unexpected adverse weather conditions.

Figure 3-2

## FACTORS IN ENCOA

difficulty in defining a true zero level for the attributes. As a result, some caution is required in interpreting the numerical scores, for while one can make relative comparisons (e.g., better or worse), one cannot make absolute comparisons (e.g., good or bad).

The third step in assessing the total utility of alternative OPFOR courses of action is to specify the relative importance (or weight) of the attributes within the hierarchy. The factors on each level are compared, by proceeding from bottom to top, to determine the relative importance of the range of variation across the options. Since the options are scored on a relative scale, the weights represent the importance of the range between the best and worst options on each attribute at that level of the hierarchy. For example, if the difference between the OPFOR courses of action on fields of fire is the most important difference among any of the terrain subfactors, it is arbitrarily given a weight of 100. The intelligence analyst then must assign a relative weight to the second most important difference among the terrain subfactors, the third most important, and so on, each weight reflecting the percentage worth of the difference under consideration to that judged most important and assigned a weight of 100. After weighting all the terrain subfactors, the analysts weight all the subfactors within each of the other four major factors or categories.

After all the above scores and weights have been entered by the user, the final judgmental operation required is to assign importance weights to each of the five categories. To accomplish this, a set of five factors consisting of the top-weighted factor from each category is presented. Again, the intelligence analyst is required to judge the relative importance of the magnitude of the difference between the



courses of action scored poorest and best on each of these factors and to rank and weight these differences just as before. This operation has the effect of adjusting factor weights by the importance weighting of the category of which each is a part. If, for example, the four factors under weather had been assigned weights of 100, 80, 50, and 30 on the basis of their relative importance within the weather category, and the weight then assigned the weather category was 50, the adjusted weights for the weather factors would become 50, 40, 25, and 15.

As Kibler et al. (1978) discuss at length, the process of assigning scores to courses of action (i.e., specifying the one which is best on a factor, worst, and intermediate) is found by most people to be an easy task. The process of assigning importance weights to magnitudes of difference is, however, initially an unfamiliar way of thinking for most. Unless users of the aid are carefully briefed and prompted in early trials, there is a tendency for many to slip into the conventional (but, in this context, erroneous) pattern of assigning weights to the generally perceived importance of a factor, rather than to the importance of the difference in value between the extreme courses of action on a factor. With practice, the correct frame of reference for judging importance weights becomes routine. Even then, however, there remains an uncertainty band around the importance weights entered into the model. The individual may have entered a weight of, say, 70 for a factor but was really uncertain as to whether that value might just as well have been 60 or 80. When such uncertainty enters the picture (as is usually the case), it is of great importance to know whether variation of the judgmental inputs within the decision maker's band of error would shift the indicated course of action selection from one option to another--a matter of sensitivity testing.

In the fourth step, one combines the scores of step two and the relative weights of step three to obtain an overall utility value for each alternative. The utility values are obtained by multiplying the bottom-level value score of each option by its relative weight to obtain a score for the option at the next level. This procedure continues until each option receives an overall utility score at the top of the hierarchy. Since the calculations are simple arithmetic, they are readily performed by ENCOA. Assuming that the scores and weights are valid and that the model captures the salient factors relevant to the situation, the course of action yielding the highest weighted score represents the most likely enemy course of action in the opinion of the participating intelligence analysts. 4

The fifth and final step in utilizing ENCOA is sensitivity analysis. Different sensitivity analyses can be performed to systematically test the sensitivity of the total utility scores to variations in the weights assigned to subfactors. Sensitivity analysis can be useful to a group of intelligence analysts, for example, who have conflicting opinions about the importance of particular factors in the hierarchy. The analysis would reveal whether the differences in opinion significantly affect the resultant total utilities of the options. By showing the implications of differences of opinion, ENCOA reduces the emotional aspects of disagreement by promoting a task-focus toward evaluating which differences of opinion truly make a difference overall.

### 3.2 A Bayesian Aid for Template Revision

The iterative templating process proposed in Circulars TC30-27 and TC34-3 can be represented quantitatively by Bayes' Theorem, which is shown in equation [1].

|                          |   |   |   |                              |
|--------------------------|---|---|---|------------------------------|
| $\frac{P(H_1)}{P(H_2)}$  | x | $\frac{P(D H_1)}{P(D H_2)}$                       | = | $\frac{P(H_1 D)}{P(H_2 D)}$  |
| (Prior<br>Probabilities) |   | (Conditional<br>Probabilities)                    |   | (Posterior<br>Probabilities) |
| Situational<br>Template  |   | Event<br>Templates;<br>Event Analysis<br>Matrices |   | Decision<br>Templates        |

The situation template shows how the enemy force would probably look for different courses of action; therefore, it specifies, at a minimum, the initial hypothesis for Bayes' Theorem. If the situation template also provides an initial estimate of the most likely course of action, as we assume it will after analysts have developed the first decision-support template, then it specifies the prior probabilities for the hypothesis in some qualitative form.

The event template identifies the information required to support each of the initial hypotheses. Consequently, the information within each event template represents, in qualitative terms, conditional probabilities, for if the enemy actually took a particular course of attack, then certain events have a higher probability of being observed than others. Furthermore, the information within all the event templates represents, again in qualitative terms at present, likelihood ratios [i.e.,  $P(D/H_1)/P(D/H_2)$ ] that indicate how much more likely certain events are to be observed than others for one course of attack than another.

Finally, the decision-support template represents the intelligence estimate in graphic form. In order to develop this template, the analysts must use collected intelligence data to revise their initial hypotheses about the enemy's most likely course of attack. Consequently, the decision-support template represents, again in qualitative terms, the posterior probabilities in Bayes' Theorem.

Reviews of psychological research in which subjects' final probability estimates have been compared with those prescribed by Bayes' Theorem have shown consistently that humans are suboptimal processors of probabilistic information; see, e.g., Fischer, Edwards, and Kelly (1978) and Slovic and Lichtenstein (1971). Although they typically revise their opinions in the same direction as Bayes' Theorem, subjects do not revise them enough; they are conservative. This finding could have great implications for IPB, for if analysts using IPB are conservative information processors, then they are not drawing implications from the data as fast as they could be with Bayes' Theorem. Their estimates about enemy courses of action may well be suboptimal because they will not have sufficiently revised their opinions to take full account of the certainty in the data. Consequently, the entire templating process will not convey as much information to commanders as it should. The time available for friendly tactical decision planning and implementation may be reduced considerably if intelligence analysts are conservative information processors.

General decision aids, called Probabilistic Information Processing (PIP) systems have been developed to ensure that human judgment is consistent with Bayes' Theorem for a number of intelligence problems (e.g., see Peterson et al., 1976). Such a decision aid is now being developed to help tactical intelligence analysts revise their judgment about the most likely OPFOR course of action on the basis of new information. This aid is being designed so that it can be readily integrated into the proposed, iterative IPB analysis process. Consequently, it will provide an important adjunct to the development and utilization of IPB templates. The decision aid is scheduled for initial evaluation during 1981.

The Bayesian judgment aid will probably operate in the following manner:

(1) the analysts define the  $n$  different enemy courses of action (COAs) under consideration (i.e., enter a brief [ $\leq 10$  character title]);

(2) the analysts enter a set of prior probabilities for the  $n$  potential courses of action;

(3) for a given datum, the analysts input a brief title and the probability of that datum conditional upon each COA being considered;

(4) the analysts inspect the posterior probabilities (or likelihood ratios);

(5) they revise any posterior probabilities that are counter-intuitive; and

(6) the analysts report on potential enemy COAs based on the probabilities after Step 5 or return to Step 3 if there are additional data.

Step 5 is necessary since any redundancy or facilitation in the data is not likely to be taken into account in providing the probability estimates in Step 3. For the probabilities in Step 4 to always be correct, without some revision at Step 5, all data must be independent. An alternative to Step 5 would be to require that the probabilities estimated in Step 3 be conditional not only on the hypothesized COA but also upon all data that have come before. This type of probability estimate is quite difficult, however,

and is most easily performed using a Bayesian hierarchical (staged) inference (BHI) model rather than the simple model proposed for use here.

The ability to use a Bayesian framework to represent the different judgments inherent in revising the IPB templates is illustrated in the above steps. Step 1 represents the different OPFOR courses of action represented in the situation template. Step 2 represents the relative likelihood of these actions at the end of one iteration of the IPB analysis process. Step 3 represents the judgments in the event templates and event matrices, which indicate the relative likelihood of having collected the newly acquired data on the basis of the enemy actually taking different courses of action. Steps 4, 5, and 6 represent the intelligence analysts' estimates of enemy intent, as represented graphically in the decision-support template.

It is important to note that a Bayesian aid also can be used even if there is no revision of IPB templates. In this case, the prior probabilities are assumed to be equal for each enemy course of action unless the analysts think certain actions are more likely than others (Step 2). The analysts then either estimate (1) the probability of the individual intelligence datum conditional on each of the hypothesized courses of action as the datum is collected (Step 3), or (2) the probability of all collected intelligence data conditional on each action. In the former case, Bayes' Theorem generates posterior probabilities after collecting each datum; the posterior probabilities are then the prior probabilities that are revised on the basis of the next datum. In the latter case, Bayes' Theorem generates the final posterior probabilities. The former case is recommended in order to minimize conservatism in the analysts' final estimate of enemy intent. Notice that while

the posterior probabilities are constantly revised on the bases of new information, the decision-support template is not because it is not developed until the analysts have collected the data necessary for the final estimate of enemy intent.

ENCOA also can be used for revising decision support templates on the basis of collected intelligence data. During the next iteration, the analysts modify (1) the score of each OPFOR course of action on each of the attributes in the hierarchy to represent the implications of collected data, and (2) the weights on the attributes at each level, if the collected data has altered the relative importance of going from the lowest to the highest scores on the attributes. The scores and weights are then combined to indicate the most likely enemy course of action. Again, sensitivity analysis provides a means for determining the effect of using different scores and weights on overall judgments of enemy intent. The overall utility scores for each OPFOR course of action can be readily represented in graphical form in the next decision-support template.

An advantage of using Bayes' Theorem instead of multi-attribute utility theory to represent quantitatively the judgments inherent in template revision is that the posterior probabilities can be readily incorporated into an expected utility theoretic framework for friendly tactical decision making. This framework is represented pictorially in the decision tree shown in Figure 3-3. In this representation, the friendly commander can take either action #1 or action #2. Each action will have a particular outcome (or consequence), depending on the course of action actually adopted by the enemy. Furthermore, each outcome will vary in utility (or value) to the friendly commander. Actual enemy intent is, of course, assumed to be unknown at the time of the decision.

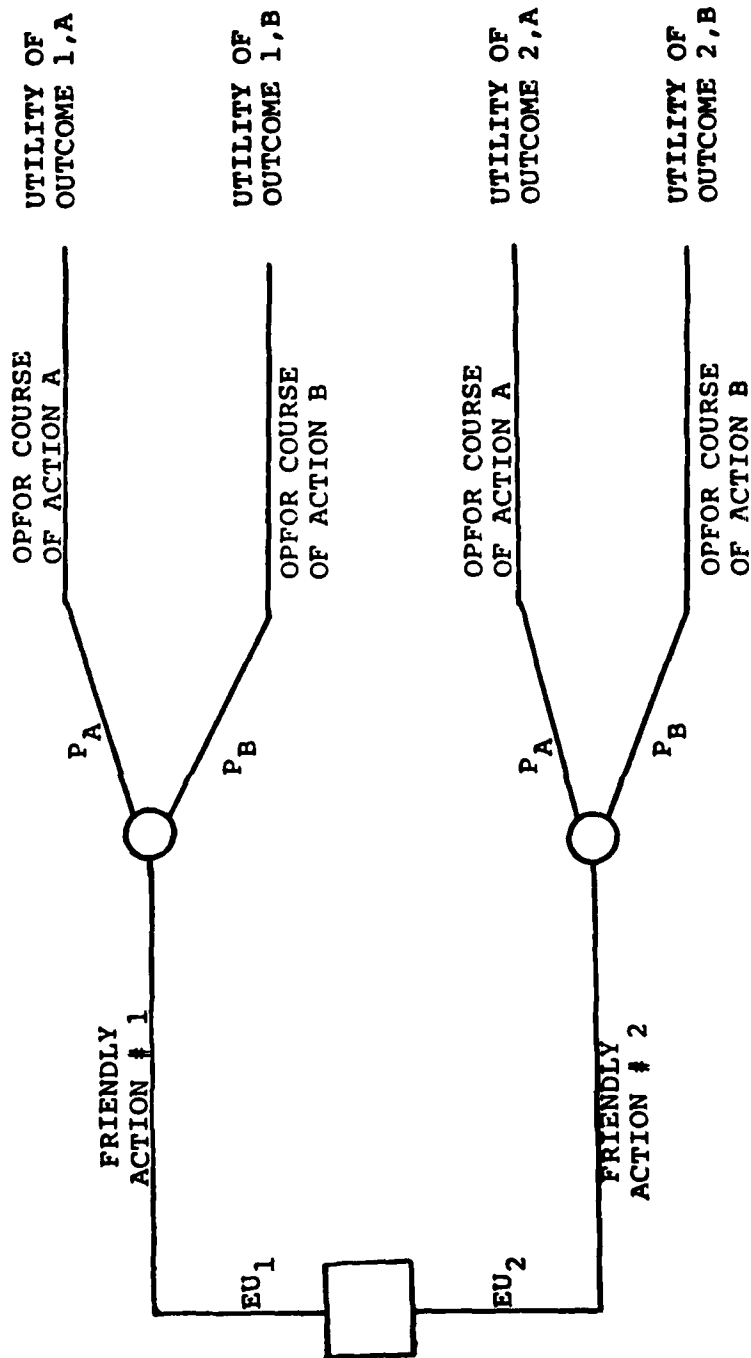


Figure 3-3

DECISION TREE EXAMPLE REPRESENTING THE APPLICABILITY OF  
EXPECTED UTILITY FRAMEWORK FOR TACTICAL DECISION MAKING



Bayes' Theorem can be used to indicate the probability (or likelihood) that the enemy is taking course of action A or B on the basis of collected data. This information can be represented pictorially in the decision-support template presented to the friendly commander. In addition, Bayes' Theorem can be used to analytically revise the relative likelihood estimates for different enemy courses of action (e.g., A and B in Figure 3-3) on the basis of newly collected data organized in the decision matrices proposed in Circulars TC30-27 and TC34-3. Again, the relative likelihood estimates can be presented to the friendly commander in the decision-support template.

Expected utility theory provides an analytic procedure for combining these relative likelihood estimates with the friendly commanders' estimates of the utility of different outcomes resulting from their and the enemy's actions. In terms of Figure 3-3, the friendly commander should, first, multiply the utility and probability estimate for each of the four branches of the decision tree shown in Figure 3-3, and then, sum the two resulting values for each action to determine the expected utility of each action. The commander then should select the action with the highest expected utility in order to ensure the greatest degree of success over time. In this fashion, the posterior probability judgments of enemy intent that are inherent in template revision can be readily incorporated into friendly tactical decision making through an explicit, retraceable analysis process.

### 3.3 Summary

This section describes two judgment aids for improving the judgmental process inherent in IPB. The first aid uses multi-attribute utility assessment techniques in order to

facilitate the development of the initial decision-support template. The judgment aid is called ENCOA, for Enemy Courses of Action. ENCOA provides analysts with a systematic procedure for evaluating each potential OPFOR course of action on twenty-four factors affecting enemy intent. In addition, ENCOA can be used to present quantitatively and pictorially the scores, weights, overall utilities, and subsequent sensitivity analyses to the friendly commander. Such information describing (1) how the analysts reached their conclusions about the most likely OPFOR course of action, as well as (2) the implications of differences in opinion among the analysts, represent an important adjunct to the graphic decision-support template.

The second decision aid uses Bayesian assessment techniques to facilitate the revision of decision-support templates on the basis of newly collected data represented in the event templates and event analysis matrices. The iterative process for revising IPB templates can be represented quantitatively by Bayes' Theorem. Psychological research comparing subjects' final probability estimates with those prescribed by Bayes' Theorem has shown that subjects do not revise their final probability estimates far enough; they are conservative. Therefore, Bayesian judgment aids, called Probabilistic Information Processing systems, should help analysts draw better implications from collected intelligence data. These implications, represented as probability estimates, can then be incorporated into the event and decision support templates. Consequently, such aids should help analysts implement the template revision process outlined in Circulars TC30-27 and TC34-3.

#### 4.0 CONCLUSION

Intelligence Preparation of the Battlefield represents a major step toward improving procedures for correlating data with enemy intent. However, it can be improved, for the process whereby input (new intelligence data) is translated into output (templates) necessarily depends on analysts' judgments about the implications of multiple pieces of potentially fallible data. Except for terrain analysis (Step 3) and weather analysis (Step 4), Circulars TC30-27 and TC34-3 fail to tell intelligence analysts how they are to make the judgments necessary to implement the proposed IPB analysis process. Furthermore, they fail to describe decision-analytic techniques and judgmental aids that are available (or being developed) to help analysts make the necessary judgments. Scientific research on causal inference strongly suggests that such techniques and aids would improve (1) the cognitive skills and, thus, the judgmental accuracy of intelligence analysts developing IPB templates, and (2) the communication process for conveying the reasons for these judgments to tactical commanders.

## REFERENCES

- Adelman, L.; Donnell, M. L.; and Phelps, R. H. Intelligence Preparation of the Battlefield: Critique and Recommendations. Technical Report PR 81-4-304. McLean, Virginia: Decisions and Designs, Incorporated, February, 1981.
- Bowen, R.J.; Halpin, J.A.; Russell, P.T.; and Staniforth, B.J. Tactical order of battle: A state-of-the-art survey. (Technical Paper No. 265). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, October, 1975.
- Brunswik, E. The conceptual framework of psychology. International Encyclopedia of Unified Science. Vol. 1, No. 10, Chicago: University of Chicago Press, 1952.
- Brunswik, E. Perception and the representative design of psychological experiments (2nd Ed.). Berkeley and Los Angeles: University of California Press, 1956.
- Fischer, G.W.; Edwards, W.; and Kelly, C.W., III. Decision Theoretic Aids for Inference, Evaluation, and Decision Making: A Review of Research and Experience. Technical Report TR 78-1-30. McLean, Virginia: Decisions and Designs, Incorporated, February, 1978. AD A953962
- Intelligence Preparation of the Battlefield (IPB). (Working Paper Draft TC 30-27). Fort Huachuca, Arizona: U.S. Army Intelligence Center and School, December, 1978.
- Intelligence Preparation of the Battlefield. (Training Circular TC 34-3). Headquarters, Department of the Army, Washington, DC, in preparation.
- Johnson, E.M.; Spooner, R.L.; and Jaarsma, D. The perception of tactical intelligence indications by intelligence officers. (Technical Paper 278). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, April, 1977.
- Kibler, A.W.; Watson, S.R.; Kelly, C.W., III; and Phelps, R.H. A prototype aid for evaluating alternative courses of action for tactical engagement. (Technical Paper TR-78-A38). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, November, 1978.
- Patterson, J.F., and Phelps, R.H. Computerized procedures guide: Decision aid for evaluating enemy courses of action (ENCOA). Working Paper Draft. Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, January, 1980.

Peterson, C.R.; Randall, L.S.; Shawcross, W.H.; and  
Ulvila, J.W. Decision Analysis as an Element in an  
Operational Decision Aiding System (Phase III).  
Technical Report 76-11. McLean, Virginia: Decisions  
and Designs, Inc., October, 1976.  
AD A034037

Slovic, P., and Lichtenstein, S. Comparison of Bayesian  
and regression approaches to the study of information  
processing in judgment. Organizational Behavior and  
Human Performance, 1971, 6, 649-744.

